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During this period of the grant I worked in the following three general areas:

1) Direct and inverse problems for waves in random media. This is the principal focus of the work funded

2) Convection enhanced diffusion

3) The effect of normal time dispersion on laser beam self-focusing

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Final Technical Report for AFOSR grant F49620-92-J-0098 for research in Direct and Inverse Problems in Random Media for the period 10/1/1993-10/31/1994

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1 Introduction

During this period of the grant I worked in the following three general areas:

- Direct and inverse problems for waves in random media. This is the principal focus of the work funded
- Convection enhanced diffusion
- The effect of normal time dispersion on laser beam self-focusing

Copies of all papers have been sent to Dr. A. Nachman. The unpublished ones can also be obtained by anonymous ftp from the Internet at math.stanford.edu and from Mosaic's World Wide Web: http://www-sccm.stanford.edu.

2 Graduate students supported by grant

Two of my students from the Courant Institute, Gadi Fibich and Tomasz Komorowski obtained their Ph.D. and got jobs at UCLA and Michigan State University, respectively. They were supported by this grant and by a grant from the Dean of Humanities and Sciences of Stanford University that was given to me when I cam here from the Courant Institute in Sepetember 1993. My last graduate student at Courant, Hongwei Cheng, is completing the second part his Ph.D. thesis under the supervision of Leslie Greengard. He is applying for a job for next Fall.

I have three thesis students here at Stanford. Liliana Borcea (in the SCCM program) is working on network approximations for elliptic equations with high contrast coefficients. She has made enormous progress over the last several months and is only in her third year so she will be here again next year. We are now completing the first of a series of papers on the work. She is supported

by a new grant from AFOSR for research on the mathematics of underground electromagnetic tomography. She was also supported by the Dean's grant. J. Berryman from Livermore, who has a lot of experience in this field, is collaborating closely with us.

The second thesis student is Knut Solna, also from the SCCM program, and he is working on seismic wave propagation. He has analyzed well log data from the North Sea and is working on a theory of front propagation in randomly layered media. He is a little behind schedule because I underestimated the difficulty of analyzing the data and the complexity of the theory. He is in his fourth year and I expect him to be here next year also. He is supported by this AFOSR grant for direct and inverse problems in seismology. We are in close contact with Jon Claerbout's group and I believe that Jon is likely to support him partially next year. Solna was partially supported by the Dean's grant last year.

The third thesis student is Leonid Ryzhik in Mathematics who started out as J. Keller's student and is now working with me and with Keller. He is working on a derivation from first principles of a transport theory for elastic waves in random media. He has made excellent progress so far and a first paper on the work is nearly finished. The results are interesting, surprising and could have considerable impact in seismology. We are in close contact with R.S. Wu at the Institute of Tectonics at UC Santa Cruz who has a lot of experience on the use of transport theory in seismology. Ryzhik is partially supported by the Dean's grant and by a new grant from the National Science Foundation that we got jointly with Wu. He was partially supported by this AFOSR grant last year.

3 Invited lectures

I gave lectures at: Caltech, UC Santa Cruz, UC Berkeley, Lawrence-Livermore National Lab, Notre Dame, Mathematical Institute in Berlin, AFOSR contractor's meeting in Albuquerque, NSF-sponsored summer school at the University of Crete, Society of Exploration Geophysics meeting at Stanford, Univerity of Minnesota, Whichita State University, University of Arizona.

I was an invited speaker at the International Congress of Mathematical Physics in Paris in July. I was Ordway Visiting Professor at the University of Minnesota in September. I was chairman of the organizing committee for the 1994-95 year on Waves and Scattering at the Institute for Mathematics and its Applications at the University of Minnesota.

4 Research papers

Published in 1994

- *Convection enhanced diffusion for periodic flows* (with A. Fannjiang), SIAM Journal on Applied Mathematics, 54, (1994) pp. 333-408.
- *A functional limit theorem for waves reflected by a random medium* (with S. Weinryb), Applied Mathematics and Optimization, vol 30, (1994), pp. 307-334.
- *Reflection of wave fronts by randomly layered media* (with P. Lewicki), Wave Motion, 20, (1994) pp. 245-260.
- *Pulse stabilization in a strongly heterogeneous layered medium* (with R. Burridge and P. Lewicki), Wave Motion, 20, (1994) pp. 177-195.
- *Water waves in disordered media* (with A. Nachbin) Comp. Appl. Math. vol 13, no. 3, (1994), pp. 235-245.

Accepted for publication

- *Statistical inversion from reflections of spherical waves by a randomly layered medium* (with M. Asch, M. Postel, B. White and W. Kohler). To appear in the J. of Comp. Acoustics. This is the completion of a cycle of work that we started in 1987 and reported in full in our 1991 SIAM Review paper (vol 33, pp. 519-626). It is the first time a statistical inversion is attempted with reflected data that is very noisy and yet information can be extracted from it.

- *Diffusion in Random Media* in Surveys in Applied Mathematics, to appear in 1995. This is an introductory survey of homogenization methods.

In refereeing process

- *Diffusion in turbulence*, with Albert Fannjiang, submitted to Stochastic Processes and Related Fields. The main result is proof of a homogenization theorem for convection-diffusion when the stream function is only square integrable.

- *Convection enhanced diffusion for random flows*, with Albert Fannjiang, submitted to the Journal of Statistical Physics. This is an extension to random flows of our paper in SIAM Journal of Applied Mathematics, which appeared in 1994.

- *Modulational stability of periodic solutions of the Kuramoto-Shivashinski equation*, with D. Papageorgiou and Y. Smyrlis, accepted by the SIAM Journal of Applied Mathematics. The main point here is a novel high-order stability analysis that probes the structure of a class of solutions of interest in many applications, for example in interfacial stability in two-phase flows.

- *Slow flow past a periodic array of spheres at low Reynolds number*, with Hongwei Cheng, submitted to the SIAM Journal on Applied Mathematics We give an analytical solution to an old problem which was solved at $Re = 0$ by Hasimoto in 1958 and for a single particle with small Re by Proudman and Pearson in 1957.

- *Self-focusing of strong laser pulses*, with V. Malkin. Submitted to Physical Review Letters. We study the influence of time dispersion on strong laser pulses. There are some interesting applications of this work to laser surgery which is the subject of the thesis of G. Fibich.

- *Beam Self-Focusing in the Presence of Small Normal Time Dispersion*, with G. Fibich and V. Malkin, submitted to Phys. Rev. A. This is based on the thesis of Fibich and contains extensive numerical computations.

- *Motion In A Random Incompressible Flow With Drift*, with T. Komorowski, submitted to Annals of Applied Probability. This is a theoretical study of a complicated and still not completely solved problem, based on Komorowski's thesis

- *Localization and mode conversion for elastic waves in randomly layered media*, with B. White and W. Kohler, submitted to Wave Motion. This is a detailed study, from first principles, of elastic wave localization phenomena and includes numerical computations. It is the first study of this kind for elastic waves.

In preparation

- *Pulse reflection of waves by locally layered random media*, with W. Kohler and B. White. This an extension to *locally* layered random media of our work in SIAM Review in 1991. It has interesting applications in exploration seismology.

- *Adapted spectral estimation of locally stationary signals*, with S. Mallat and Z. Zhang. This is a detailed study and implementation of wavelet-based methods for spectral estimation of processes that are close to being stationary. We give applications to reflection seismology. The implementation is based on a flexible collection of software tools developed by Zhang who is a postdoctoral visitor in the Mathematics Department.

- *Networks for Elliptic Partial Differential Equations*, with L. Borcea. This an asymptotic analysis that reduces a boundary value problem to a set of algebraic equations when the coefficients have high contrast. Based on Borcea's thesis.

- *Transport equations for wave propagation in random media*, with L. Ryzhik and J.B. Keller. Primarily for elastic waves and with seismological applications in mind. Based on Ryzhik's thesis.